Evolution and Water Ice Content of Layered Materials in the Northern Polar Deposits of Mars. W. M. Calvin[1], F. P. Seelos[2], S. L. Murchie[2], K. D. Seelos[2], T. N. Titus[3], and P. B. James[4], [1] Dept. Geological Sciences, University of Nevada, Reno NV 89557, wcalvin@unr.edu [2]Applied Physics Laboratory, Laurel, MD [3]U. S. Geological Survey, Flagstaff, AZ [4]Space Science Institute, Boulder, CO

Introduction: The finely layered units of the polar layered deposits were first identified in Viking imagery [1]. Recent work has shown that the layered patterns may reflect a periodicity that is related to past climate epochs [2]. However, the stratigraphy is largely traced to texture rather than albedo of surface units [3,4]. Bright and dark streaks related to wind deposition or removal of thin frosts or dust overprint the fine scale layering observed in the troughs [5]. The first northen summer observed by Mars Reconnaissance Orbiter (MRO) instruments allowed detailed examination of sections of the previously described stratigraphy [3] and examination of sustained bright patches [6] using CRISM, MARCI and CTX imaging and spectral techniques.

Observations: We concentrate on MRO observations acquired in the first phase of mapping from late September, 2006 through January of 2007, corresponding to Ls 113 to 173. Later observations show the development of polar hood conditions that tend to obscure the residual ice and polar layered deposits (PLD). We have constructed daily MARCI color polar mosaics to examine atmospheric phenomena that may be related to surface albedo evolution observed with CTX and CRISM. Seventeen full spatial and spectral resolution CRISM observations (FRTs) were acquired during this time frame of scattered locations (Figure 1).

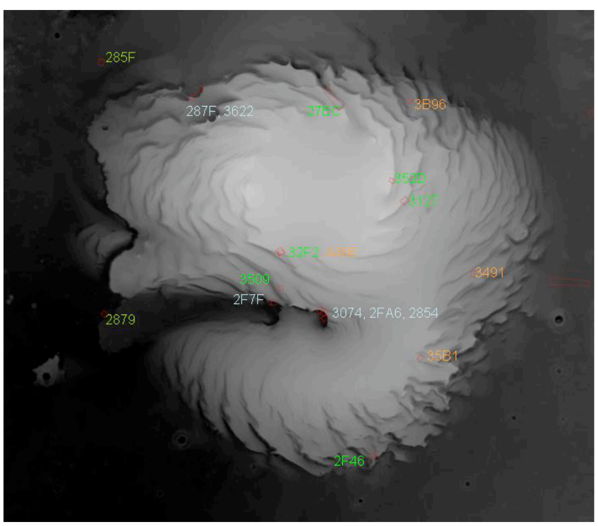

Figure 1: Small red outlines show FRT footprints over MOLA topography. FRT observation number is given adjacent to the footprint.

Ablation of previously sustained bright regions: Calvin and Titus [6] identified frost mobility and several regions where albedo remained high throughout the northern summer season. One region, dubbed "Vostok" was the subject of repeated observations by CTX and CRISM. CTX imagery shows that the upper surface undergoes ablation and reduction in albedo between November 12 and 27, 2006. The margins of the exposed area do not change significantly until January 7, 2007 (Ls=162), when a brighter margin within the ablation zone appears.

Examination of CRISM FRT and MSW (multispectral window) observations shows that the underlying material in the "dark" region is still very water ice-rich, with prominent ice absorption features (Figure 2). The earliest MSW observation shows the region already defrosted, thus the ablation event occurred prior to November 19th. MARCI color mosaics show a large dust cloud propagating up the Chasma Boreale on November 16th that may be responsible for the frost removal event.

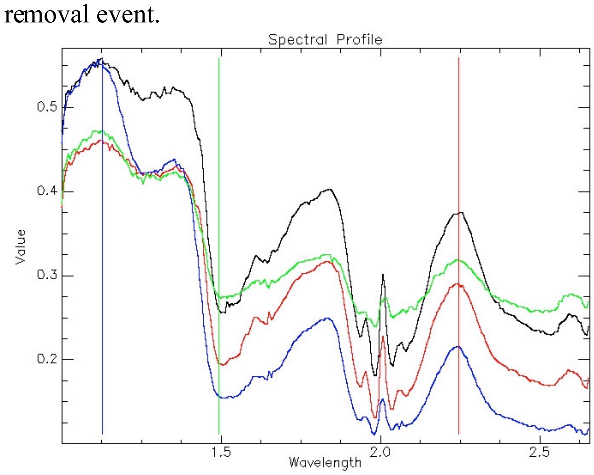

Figure 2: Representative spectra from FRT_32F2, with simple atmosphere and cos(i) correction. All regions, including dark layers and lower albedo upper surface units show prominent ice absorptions.

Water Ice Content of exposed layers: Of the 10 FRTs of upper surfaces of the PLD 6 show fine layering and stratigraphy (green image numbers in Figure 1). Similar to Vostok, most dark layers within the upper unit are also water ice-rich. Simple measures of ice content include band depth of the 1.5 μm absorption feature, slope down from 1.15 to 2.25 μm, and spectral rise from 3.0 to 3.6 μm. Langevin et al. [7] have noted that icy particles in the atmosphere contribute weakly to these three parameters, but that the spectral shape beyond 3-µm can be quite diagnostic in discriminating ice cloud from icy surfaces.

We have explored these parameters in several of the FRT image cubes and find that the 1.5 µm band depth (as determined in simple 3 channel ratios) can consistently track exposed layers, regardless of albedo. As shown in Figure 3, ice content of layers is not correlated to albedo, and likely is an independent method for determining stratigraphy or layer "packets". Continuous horizontal banding in 1.5-µm band depth is also seen in multispectral mosaics that extend over tens of kilometers [8]. Future work will concentrate on determining layer sequences, their correlation with layers identified based on albedo and morphology, and if there is consistency between these spectral parameterizations and previously noted "marker" beds.

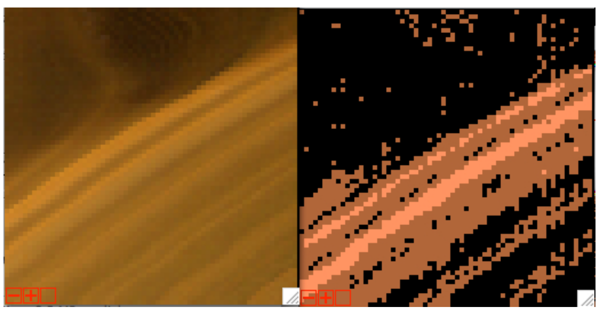

Figure 3: CRISM color composite (RGB: 0.73, 0.60, 0.44 µm) compared with a density slice of the 1.5 µm band depth. Band strength increases from black to brown to sienna. From FRT_27EC, unprojected but corrected for cos(i) and atmospheric gas absorptions.

Water Ice Content of Basal Layer and lower PLD Exposures: Murchie [9] and Seelos et al. [8] both noted that the basal unit (BU) exhibits weak to no water ice signatures based on the 1.5 µm band depth. However Herkenhoff et al. [4] found that based on polygonal fractures and mass wasting of blocks that the brighter basal units should be volatile rich. Improved calibration gives us increased confidence in weak ice signatures at 1.5 µm and we find that the 3.0 to 3.6 µm rise is diagnostic of ice in lighter toned floor materials (Figure 4). Of the 6 FRTs that cover the lower units of the PLD (light blue image numbers in Figure 1) initial analysis shows that portions of the basal unit material are ice-cemented, particularly light layered materials adjacent to the upper BU scarps (Figure 4, also FRT_2FA6, not shown here). Detailed modelling of the spectral shape longward of 3-µm is needed to confidently identify ice in the darkest floor materials, but there is evidence that lighter ejecta surrounding craters in the Chasma floor and lighter units of the differentially eroded basal layers contain some ice (FRT_287F, not shown).

The lower portion of the PLD just above the basal unit is found to be relatively ice-rich compared to layers higher up in the sequence, with the uppermost surface the most ice-rich [8, this abstract]. Though coverage is sparse, this trend is observed in all high resolution images at widely separated locations. In FRT_2854 (Fig 4) light colored ice rich cones are seen on top of the basal unit scarp in contact with these upper ice-rich PLD layers.

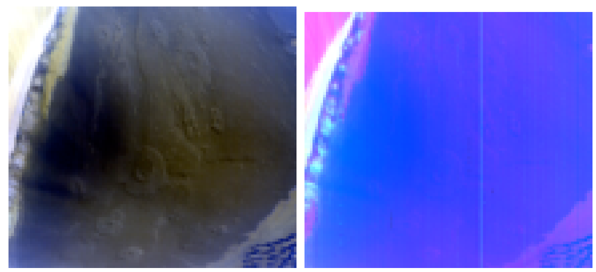

Figure 4: CRISM approximate true color composite (left) and water ice emphasis (right) for FRT_2854 near the head of Chasma Boreale. The visible color uses RGB bands (0.73, 0.60, 0.44 µm). The false color ice emphasis uses the RGB combination: albedo at 1.1 µm, the 1.5 µm band depth, and the spectral rise from 3.3 to 3.6 µm. Icy materials are white, cyan and magenta, ice-poor units are blue. Magenta colors clearly highlight spatially coherent units, including layered basal material (upper left) and light toned areas surrounding dunes (lower right).

Summary: Water ice content of low albedo "dirty" layers can confidently mapped and traced to intrinsic layer properties. Large scale stratification is observed within the PLD layers with sections just above the BU more ice rich than intermediate sections. Many low albedo units still have very strong water ice signatures. Future work will quantify amount of water involved in observed ablation losses and to define a stratigraphy based on ice content that might be traceable to interior layers observed by MARSIS and SHARAD.

References: [1] Cutts, JGR, 78, p. 4231, 1973. [2] Milkovitch and Head, JGR, 100, doi:10.1029/2004JE002349, 2005. [3] Fishbaugh and Hvidberg, JGR, 111, doi:10.1029/2005JE002571, 2006. [4] Herkenhoff et al., Science, 317, p. 1711, 2007. [5]Howard, Icarus, 144, p. 267, 2000. [6] Calvin and Titus, Planet. Space Sci. in press. [7]Langevin Y. et al. JGR, 112, doi:10.1029/2006JE002841, 2007. [8]Seelos, F. P. et al. LPSC 38, #2336 2007. [9]Murchie S. L. LPSC 38, #1472 2007.